Theory of Nuclear Excitation and their Astrophysical Relevance *

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New modes of excitation in neutron-rich nuclei are described by an advanced Hartree-Fock-Bogoljubov (HFB) plus multiphonon approach.

Here, we report on recent spectroscopic studies in N=50 isotones based on the Quasiparticle-Phonon Model (QPM). The systematic calculations of dipole strength functions in these nuclei indicate enhanced $E1$ strength in the energy range from 6 to 10 MeV in agreement with the experimental observations [1]. From quasiparticle-random-phase approximation (QRPA) calculations, the energy region below E*$\leq$9 MeV is related to the pygmy dipole resonance (PDR) which total strength smoothly decreases with increasing charge number Z closely correlated with the thickness of the neutron skin. We point out that the QRPA is unable to account for the detailed description of the dipole strength function. However, three-phonon QPM calculations can reproduce the fine stucture of the latter fairly well as it follows from the comparison with the experiment [1]. Such precise knowledge of nuclear response functions is very important for the determination of photonuclear reactions cross sections for the astrophysics.

The microscopic strength functions have been implemented successfully into statistical reaction codes to investigate n-capture cross sections of astrophysical importance [2]. Our recent result on the n-capture cross section of the reaction ^{85}Kr(n,γ)^{36}Kr [2] is shown in Fig. 1. As seen, the microscopic calculations are in a very good agreement with the experimental data on the one hand and the HFB+combinatorial results on the other hand [2]. This agreement is confirming the predictive power of involved many-body theoretical methods like the QPM for exploratory investigations of n-capture reaction rates in hitherto experimentally inaccessible mass regions.

Recently, the fine structure of the $M1$-Giant Resonance (GR) in the nuclide ^{90}Zr was investigated [3]. Measurements performed in the range 7-11 MeV reveal a $M1$ resonance structure with centroid energy of 9 MeV and a summed strength of 4.5(4) μ_N^2. These data are fully reproduced in three-phonon QPM calculations [3]. The theoretical investigations which are presented in Fig. 2 indicate a strong increase of the contribution of the orbital part of the magnetic moment due to coupling of multiphononon states. Of special interest is the behavior of the M1 strength at higher energies close to and above the neutron-separation energy where the experimental accessibility is strongly reduced. For these regions, the theory predicts the existence of a strongly fragmented M1 strength with summed value of several μ_N^2. The latter is a very interesting finding which sheds light to the understanding of the long-standing problem with the quenching and dynamics of the M1 strength.

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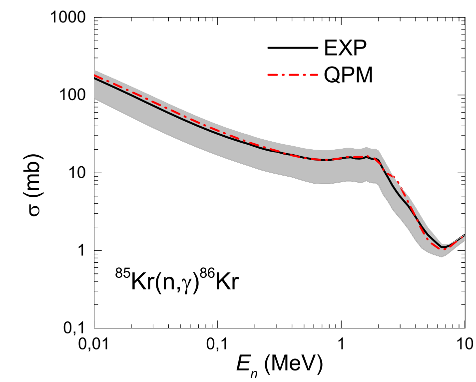

Figure 1: (color online) Cross section of $^{85}Kr^g(n,\gamma)^{86}$Kr calculated with TALYS using experimental dipole (in black) and QPM strength functions (in red) from Ref. [1]. The predicted uncertainties (shaded area) are derived from the experimental errors of the dipole strength function and from variations in the nuclear level density parameters.

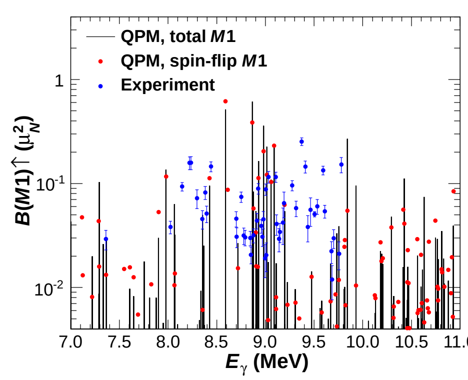

Figure 2: (color online) The measured M1 strength of discrete 1^+ levels in ^{90}Zr compared with three-phonon QPM predictions from Ref. [3].

References

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